Automatic recognition of weathered rock images by convolutional neural networks

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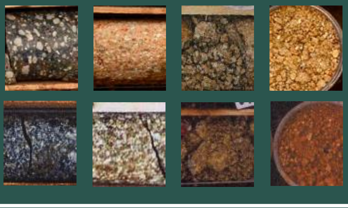
Abstract

An Automatic approach of transfer learning using **convolutional neural networks (CNNs)** to classify two Hong Kong rocks (feldsparphyric rhyolite and granodiorite) was developed. Due to the limited dataset available, **Generative Adversarial Networks (GANs)** were applied to generate synthetic rock images for training. Multiple convolutional neural networks (CNNs) trained under transfer learning were combined with an **ensemble method** to further boost the prediction performance. The model obtained an f-1 score of **82%**, and the misclassified images are mostly the geologically neighbouring classes, that are also even found to be difficult to be differentiated by trained naked eyes. A semi-automatic object detection method was deployed for quick data preparation of this project.

Introduction

- Traditionally, rock cores drilled from the ground are inspected by **logging geologists** for rock classification.
- **Automatic approach** has a strong potential to improve quality and effectiveness by providing quick and objective assistive information
- **8 rock classes** were studied



Grade	Term	Characteristics
V	Completely decomposed	Can be crumbled by hand into constituent grains
IV	Highly decomposed	Can be broken by hand into smaller pieces
III	Moderately decomposed	Cannot be broken by hand, completely stained throughout
II	Slightly decomposed	Retains fresh rock colour, only stained near joint surfaces

(GEO, 2017)

- **Convolutional neural networks (CNNs)** specialize in image classification tasks
- **Generative Adversarial Networks (GANs)** can generate synthetic images for training of CNN as a data augmentation method to enlarge the training dataset (Bowles et al., 2018)
- **Transfer learning** is a technique that borrows models pre-trained with large and complex dataset to solve a different but similar problem, with benefits including better accuracy
- **Ensemble method** that combines multiple models often give better performance than any of its constituent model alone (Ganaie & Hu, 2021)

Methodology

1 Data Preparation

- Corebox images retrieved from Ground Investigation (GI) were first **rescaled**, followed by **subsampling**
- Those processes were carried out **semi-automatically** by object detection (Faster R-CNN ResNet-50 FPN) to identify the scale reference and the rock core after a small portion was manually annotated

Corebox Image

① Detection of scale reference and rescale accordingly

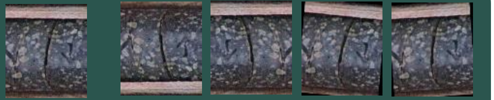
② Detection of rock core and cut into subsamples

2 Data Augmentation

- **Wasserstein Generative Adversarial Networks (WGANs)** (Arjovsky et al., 2017) were applied to generate **synthetic images**

Progressive training of a Wasserstein Generative Adversarial Network

- **Geometric data augmentation** of *flip* and *rotate* to enlarge the dataset



Original Image | Flipped Vertically | Flipped Horizontally | Rotated 4° Right | Rotated 4° Left

3 Training and Evaluation

- The CNNs were based on the pre-trained networks of **MobileNet v2**, **ResNeXt-50** and **RegNetX-16GF** available on PyTorch (Paszke et al., 2019).
- **Unweighted averaging ensemble** method to combine the three models
- 5-folds **cross validation** strategy
- Assessed by various **evaluation indices** including precision score, recall score, and f1-score and confusion matrix

Results

- Incorporation of **synthetic images** generated from GANs increases the precision score, recall score, and f1-score from (81%, 80%, 80%) to (82%, 81%, 81%) respectively.
- The precision score, recall score, and f1-score of **MobileNet v2**, **ResNeXt-50** and **RegNetX-16GF** with the incorporation of **synthetic images** are (82%, 81%, 81%), (82%, 80%, 80%) and (83%, 81%, 81%) respectively.
- The precision score, recall score, and f1-score of the **ensemble model** are (83%, 82%, 82%) respectively, higher than any of its constituent model.

Confusion Matrix

- Most of the misclassified images are **geologically neighbouring classes**, e.g., Grade IV feldsparphyric rhyolite misclassified as Grade III feldsparphyric rhyolite. Some of the misclassifications shall not be blamed for the inaccurate trained-model prediction. Weathering is a **gradual process** that may create **transitionary and intermediate features** such that the division between weathering grades is sometimes not very distinct that is **hard to assign a single grade** to.

Conclusions

- This research presented an approach of applying **GANs** for generating synthetic images for the training of **transfer learning of CNNs** with **ensemble method** on the task of rock classification. The misclassified examples suggest that the model **may achieve even higher accuracies** than the reported precision score, recall score, and f1-score of 83%, 82%, and 82%. This research project demonstrates the possibility of leveraging the artificial intelligence capability for performing rock classification. Based on the success of this project, further work will be performed to expand the rock image database by covering a wider range of rocks and other geological features encountered in rock cores.

Reference

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